BCPM 3.1--Places horizontal connecting cable from the DLC site to connect to vertical connecting cable that runs to the geographic center of each Distribution Area. A backbone cable runs vertically through the center of the Distribution Area. Branch cables emanate from the backbone cable, and drop cables run from remote terminals placed along the branch cable.

Loop Length

BCPM 1.1--Used a default value of 12,000 feet to constrain the copper loop length from the DLC to the customer. (This was a user adjustable input.)

BCPM 3.1—Tends to limit average copper loop lengths from the DLC to the customer by generally limiting the maximum ultimate grid size to 12,000 feet by 14,000 feet, latitude and longitude. If copper loop lengths from the DLC to the customer exceed 12,000 feet, the cable gauge is reduced to 24 gauge cable and extended range plug-ins are installed on loops extending beyond 13,600 feet. The ultimate grids are designed such that copper loop lengths from the DLC to the customer are unlikely to exceed 18,000 feet.

Model cap on Total Cable Length

BCPM 1.1—Did not provide for a constraint on cable length within the CBG subfeeder and Distribution Areas.

BCPM 3.1—Caps the distribution quadrant total cable length so that it does not exceed the total road distance within the distribution quadrant.

Density Zones

BCPM 1.1--Used seven density zones.

BCPM 3.1--Uses nine density zones to facilitate comparison of BCPM results with the Hatfield Model.

III. SWITCHING

Differentiating Switch Functions

BCPM 1.1--The switch curve made no distinction between host and remote switches.

BCPM 3.1--Uses separate switch models for host, remote, and stand-alone switches.

Investment Approach

BCPM 1.1--Estimated a single total switch investment.

BCPM 3.1--Calculates switching investments for each of several switch functional investment categories, using a separate curve for each category. In addition, the switch can be partitioned accurately into non-traffic sensitive (Line Port) and traffic sensitive investments.

Determining Universal Service Impact

BCPM 1.1--Provided a single input that allowed the user to specify the percent of the total switch investment that is associated with basic service.

BCPM 3.1—Identifies accurately the portion of investment that supports universal service for each central office by using a separate curve for individual switch functional investment categories.

Usage Related Inputs

BCPM 1.1--Switch curves estimated switch functional investments based only on the number of lines in the office.

BCPM 3.1--Uses a variety of inputs including call rates, usage levels, number of trunks, as well as the number of lines. BCPM 3.1 allows input of usage levels for universal service that can be independent of the usage inputs used to engineer the switch. Usage inputs can be distinguished by residence and business lines if desired. Most data items can be input on a state-specific and/or wire-center specific basis with a "fallback" feature that allows the Model to use the state-level inputs in those cases where wire-center inputs are not available.

Switch Type

BCPM 1.1—Was based on a sample of switch investments that included DMS-100 and 5ESS switches. The single switch curve, however, made no distinction between the two switches.

BCPM 3.1--Is also based on the 5ESS and DMS-100, and additionally, allows the user to specify a switch vendor, if that information is available.

Input Values

BCPM 1.1--Used responses to a data request sent to the LECs. This data request asked for discounted unit investments produced by SCIS runs. The resulting model, in essence, produced an average discount level for the companies polled.

BCPM 3.1--Is based on a similar data set produced by the BCPM sponsor companies (BellSouth, Sprint, U S West). The sponsor companies provided non-discounted switch investments for use in the switch curve. The investments are produced with SCIS runs, except for the U S West investments, which are produced using the Switching Cost Model (SCM).

Method to Estimate Investment

BCPM 1.1--Used a single means, the switch curve, for estimating wire center switch investments.

BCPM 3.1--Can use several sources of investments to determine USF costs: the switch regression curve, direct input from an ALSM, or total switch investments from any other source. BCPM 3.1 partitions the investments from other sources by functional investment category, producing accurate estimates of universal service investments by switch.

Limiting Switch Size

BCPM 1.1--Did not have an algorithm to limit switch sizes. That caused simple switch curve models to create "switches" with unreasonably large amounts of lines or usage.

BCPM 3.1--Has the capability to scan the input table to determine whether the capacity constraints for any given wire center have been exceeded. For example, if a wire center has more than a user-defined number of lines, the Model automatically inserts a new CLLI and a new switch entity.

Switch Categories

BCPM 1.1—Modeled only medium and large switches.

BCPM 3.1—The switching module includes large, medium and small switches. For small switches the user can enter fixed and variable costs, discounts, and breakpoints or can use the model default values.

IV. TRANSPORT

Approach to Interoffice Costs

BCPM 1.1--Transport was calculated as approximately 3% of switching investment.

BCPM 3.1--Creates a realistic model of the interoffice network based on the actual homing relationships between remotes and hosts, and hosts and tandems. It develops specific and accurate cost elements for efficient SONET bandwidth based on trunking configurations of specific nodes on the network.

Transport Redundancy

BCPM 1.1--Did not consider transport redundancy.

BCPM 3.1--Provides one level of redundancy via what is commonly referred to as "self-healing" rings.[52] Provides a second level of redundancy by using two sets of lines for offices served by a folded ring.[53] Includes a third level of redundancy by providing one extra DS1 for every seven working DS1s on the port side in a central office.

Level of Analysis for Transport

BCPM 1.1--Did not provide an analysis of Transport costs.

BCPM 3.1--Allows the user to run the model for a single ring, thereby enabling the user to trace the cost calculations through the logic of the Model.

Reports on Transport

BCPM 1.1--Did not provide reports on transport.

BCPM 3.1--Provides reports for each ring. Includes transport cost results for all of the rings, transport configuration of all of the rings, and universal service transport cost on a per line basis.

V. SIGNALING COSTS

Approach to Signaling Costs

BCPM 1.1-- Contained no explicit provision for signaling costs. The only costs associated with signaling are those included in the switching investment.

[52] If the fiber cable in a "self healing" ring is cut, the signals will automatically reverse their direction on the ring.

[53] A folded ring connects a small office to a single node on the SONET ring.

BCPM 3.1--Calculates signaling costs through an input table that includes per line investment. Investment figures are provided for residence and business lines in large, medium, and small companies. Investment amounts are calculated by using the Signaling Cost Proxy Model (SCPM) which:

- Creates a two tiered SS7 Signaling network using a combination of user definable inputs and LERG data;
- Uses the existing SS7 signaling network as the basis for the SCPM network;
- Uses actual data to develop the octet, millisecond and data dip needs of the network as the foundation elements to determine signaling investment; and
- Builds and costs the proper number of packet switches, on line data bases and signaling links by analyzing the octet, millisecond and data dip needs of the network.

The user can accept the default value or input the per line values. SCPM is available from the BCPM Web Site for the user to develop per line investments using their own cost data.

APPENDIX D

SWITCH CURVE METHODOLOGY

Introduction to Regression Analysis

The purpose of regression analysis is to determine, from a number of observations or measurements, whether there is a relationship between two or more variables. For example, we can use regression tools to tell us whether there is a relationship between the number of lines terminated on a central office switch and the total dollar investment in such a switch. While many people familiar with the equipment in question can say intuitively that there is such a relationship, regression analysis allows us to measure both the strength of that relationship and its magnitude.

The output of the linear regression modeling process is a set of equations, constants, and coefficients that can be used to estimate the value of the dependent variable based on the value of the independent variable. The concept of the regression coefficient is critical to understanding the operation of the BCPM switch module, as we will see later. The set of switching regression coefficients that result from this analysis is commonly known as the "switch curve".

In the case of a central office switch there is an independent variable, the number of lines, and a dependent variable, the total investment. Simple linear regression is a technique for determining how much a change in the number of lines will affect the dependent variable, total investment. The linear regression process allows an analyst to estimate the coefficients (a & b) of the following algebraic functional form:

$$Y = a + bX$$

Where:

Y = the total dollar investment

a = a constant investment amount

b = an incremental investment per line

X = the number of lines

For example, assume that a is $300,000, b is $175 and X is 10,000. Using the algebraic model, we can estimate that the total investment for a 10,000 line central office is $2,050,000.

Because regression analysis is a statistical technique, the investment amount calculated is an estimate. Hence, there will be some degree of error associated with the estimate as compared with the observed investment. The difference between the "predicted" investment and the actual investment is called the prediction error. The prediction error is minimized through the selection of the appropriate algebraic functional form (i.e., one that produces the best "fit" to the actual observed values).

A measure of how well the specified equation fits the data is the coefficient of correlation, or R^2. The coefficient of correlation is the percentage of variability in Y that is explained by the variables in the model and ranges between 0 and 1. The closer the R^2 is to 1.0, the better the model explains the variability in Y. Typically, the analyst will consider a number of independent variables in the formulation of a regression model, and eliminate those that do not significantly add to the predictive power of the model.

The above equation format also allows for the use of a variable to modify the constant coefficient (a). This "dummy variable", as it is known, can be used to differentiate between switch types. For example, if we believe that switch 1 and switch 2, from different vendors, have different fixed investments, we can make the switch vendor an input variable and have the model produce different constant investments based on the switch vendor selected. This technique is used in the BCPM switch model.[54]

[54] The dummy variable has a value of 0 if the switch is a Nortel DMS-100, and 1 if the switch is a Lucent 5ESS. This allows the model to produce a modifier to the coefficient that represents the incremental investment difference between a 5ESS and a DMS-100. Later, when the model is used to estimate investments, the dummy variable is applied to the coefficient, producing different estimates for the two switches.

While we have discussed regression in terms of a simple linear function, multiple linear regression is also commonly used. Multiple linear regression uses more than one independent variable to explain the dependent variable. Regression models producing curved lines can also be created. For example, the equation to be estimated can have the root or the square of an independent variable instead of the variable itself.

Functional Investment Category (FCAT) Rationale

A key design goal for the BCPM switch model was the ability to compute with specificity the incremental investments needed for universal service and unbundled network elements (UNEs). Previous proxy models, because they produced only a single investment number for the entire switch, were unable to calculate these investments without arbitrary and unsupportable allocations. For example, engineering studies and models can precisely quantify the investment in non-traffic sensitive equipment that is needed to provide a line port on the switch. This line port investment is a both a primary UNE and a key element of universal service. Accurate determination of this investment is critical to both UNE pricing and calculation of universal service support. Previous proxy models could do no better than assign an arbitrary percentage of switch investment to the line port. The problem was exacerbated by the fact that the percentage of the switch investment attributable to the port could vary upwards of 100% depending on the switch vendor and switch size.

BCPM solves this problem by directly estimating switch investments in six separate functional investment categories. The number of categories was kept as small as possible for simplicity while still providing enough granularity to perform meaningful UNE and universal service studies. A further challenge was to create a set of categories that could integrate investment data from the two Audited LEC Switching Models (ALSMs), SCIS and SCM. After careful analysis of the ALSMs, the BCPM Sponsors arrived at the following functional investment categories:

- **Processor Related**: This category includes both the SCIS Getting Started and EPHC primitives, and the equivalent equipment investments from SCM. The group agreed that switch peripheral processors should be placed here.
- **Line Termination** - MDF & Protector: This category is identified separately because these items form a discrete UNE in many states. Includes the Outside Plant block, Central Office block, protector frame, and protector block.
- **Line Port** - line cards and associated equipment.
- **Line CCS** - includes Umbilical Trunk CCS.
- **Trunk CCS.**
- **SS7** - Service Switching Point (SSP) equipment.

The BCPM sponsors created mapping processes to combine and cross-reference the detailed investment outputs from SCIS and SCM into this set of six categories.

Although the model was created using SCIS and SCM investments, future switch curves could be developed using any engineering-based model that produces investments for the above functional categories. These additional investments could be used as additional samples in the switch curve development or as alternatives to the ALSM data.

The BCPM sponsors chose to develop the regression model using the Lucent 5ESS and Nortel DMS-100 switches. These two switches are the predominant switches for large LECs today and are expected to be so for the foreseeable future in the United States. Discussions with the sponsor companies' engineering subject matter experts indicate that few placements of small standalone switches, such as the Nortel DMS-10 are expected in the future. Most small exchanges will be served by 5ESS or DMS remotes.

Switch Curve Development

Regression Model Conceptualization

The switching regression model included a separate investment equation for each of the six switch functional investment categories. In addition, an overall total investment equation was needed to ensure that the individual bucket equations reconciled back to a reasonable total.

Data Collection

The BCPM sponsor companies (BellSouth, Sprint, and US WEST), performed ALSM model runs for more than 1,700 central office switches and compiled the inputs and results using the mapping process described above. The ALSM runs were either performed with a zero discount level, or discounts were mathematically eliminated from the results. This ensured that the effect of possible discount differences between the companies was eliminated, and makes the regression results applicable for any company with the input of appropriate discounts into BCPM. Since the sample size was relatively large, some outliers in terms of input data (number of lines) were eliminated. Switches that had no lines in the input data were eliminated. Hosts and Standalones with no trunks were eliminated.

Table 1 - Switch Sample

	Number of Samples	Maximum Line Size	Minimum Line Size
Standalone	511	95,733	1,621
Host	314	76,112	1,017
Remote	868	12,794	209

The process of creating a regression model and testing it with real-world data was repeated several times with different combinations of variables and coefficients until a robust and statistically sound model was produced. Any independent variables that did not contribute to the ability of the model to predict total category investment were eliminated. The independent variables that were used in the final version of the model were as follows:

- Total Lines
- Calls per Line
- Trunks
- 5ESS Indicator (0 or1)

A variable measuring CCS per line was found to be statistically insignificant in the model and was eliminated. However, this input was left in BCPM with a zero value in case future regression models require it.

The following independent variables were created from the existing data:

- 5E Indicator * Total Lines
- 5E Indicator * Trunks

These variables allow for differentiation in cost characteristics between the Lucent and Nortel switches.

Analysis of Regression Results

The estimated investment category equations are shown in Table 2 for stand alone switches, in Table 3 for host switches, and in Table 4 for remote switches. Each set of investment category equations was estimated jointly to take advantage of cross equation information.

Table 2. Stand Alone Switches: Estimated Investment Category Equations

Independent Variable	Total Investment	Processor	Line Term	Line Port	Line CCS	Trunk CCS
Lines	358.74	18.46	15.74	157.96	132.74	
	(73.49)	(9.82)	(122.50)	(64.49)	(43.08)	
Trunks	314.64					522.64
	(15.73)					(148.10)
Calls	822,200	419,110				
	(33.24)	(18.18)				
5E Dummy	-220,880	-398,550			-162,030	
	(-1.56)	(-6.49)			(-1.48)	
5E Dummy*Lines	-57.44	37.74		-105.64	45.47	
	(-9.23)	(16.83)		(-37.33)	(10.15)	
5E Dummy*Trunks						-243.34
						(-60.64)
Constant		1,194,100				
		(17.49)				
R^2	0.93	0.81	0.91	0.89	0.89	0.96

Notes: t-values in parentheses under estimated coefficients[55]. SS7 investment category treated as residual.

[55] The t-value is used to determine whether the coefficients are statistically significant, that is, the likelihood that the coefficient is actually something other than zero. The critical value for this large sample size and a 95% confidence level is 1.960. Therefore, for any coefficient whose t-value is greater than 1.960 we can assume with 95% confidence that the coefficient does differ significantly from zero.

Table 3. Host Switches: Estimated Investment Category Equations

Independent Variable	Total Investment	Processor	Line Term	Line Port	Line CCS	Trunk CCS
Lines	341.87	5.98	16.57	164.12	129.36	
	(51.45)	(2.15)	(97.35)	(54.21)	(39.04)	
Trunks	481.45					562.24
	(20.99)					(69.62)
Calls	1,062,100	486,620				
	(26.68)	(13.54)				
5E Dummy	-604,800	-851,270			122,110	
	(-3.081)	(-10.02)			(0.88)	
5E Dummy*Lines	-71.64	45.83		-114.89	38.40	
	(-7.94)	(12.77)		(-30.70)	(6.69)	
5E Dummy*Trunks						-255.03
						(-23.90)
Constant		1,404,600				
		(16.38)				
R^2	0.90	0.65	0.97	0.91	0.88	0.91
Notes: t-values in parentheses under estimated coefficients. SS7 investment category treated as residual.						

Table 4. Remote Switches: Estimated Investment Category Equations

Independent Variable	Total Investment	Processor	Line Term	Line Port	Line CCS
Lines	395.02	25.53	22.04	217.86	136.43
	(125.10)	(10.64)	(125.70)	(93.35)	(46.89)
Calls	138,340	124,620			
	(38.16)	(40.22)			
5E Dummy	296,350	154,810	34,490		134,090
	(20.14)	(15.59)	(39.49)		(13.09)
5E Dummy*Lines	-118.60	14.97	-10.59	-154.85	25.60
	(-25.72)	(4.64)	(-36.25)	(-50.10)	(5.85)
R^2	0.93	0.65	0.87	0.92	0.74
Notes: t-values in parentheses under estimated coefficients.					

BCPM 3.0 Switch Curve Application

BCPM calculates the universal service switch investments in two major steps. The Switch Functional Investment Development Process computes the total discounted switch investment, by functional investment category, for each wire center in the study (Figure 1). The model can use category investments generated internally (through the switch regression model), externally (for example, from an ALSM), or from a combination of sources. The second step, the Service Specific Investment Process, calculates the per unit switching investments for universal service (Figure 2).

As Figure 1 shows, the regression coefficient table, or switch curve, that results from the regression analysis is an *input* to the Switch Functional Investment Development Process (Figure 1), within BCPM. BCPM users can easily examine and modify the regression coefficients by selecting the "Inputs" button in the program. The BCPM sponsors recommend, however, that the coefficients should only be changed as a result of a thorough and statistically validated regression analysis.

Estimating Switch Investments

The Switch Functional Investment Development Process applies the switch regression coefficients in the following manner:

Compile Input Data

In addition to the switch curve coefficients, the model compiles other inputs (independent variables) to the investment estimation including:

- standalone/host/remote status of each wire center
- switch vendor (or Lucent/Nortel market share) for each wire center
- number of switches at each wire center
- number of engineered lines per switch at each wire center
- number of engineered trunks per switch at each wire center
- usage and traffic characteristics
- busy hour calls per line
- busy hour CCS per line

Complete descriptions of these inputs, their development and default values can be found in the *BCPM 3.0 Model Methodology* and the *BCPM 3.0 Switching Inputs* documents located on the BCPM 3.0 CD-ROM.

Estimate Standalone and Host Investments

The regression model estimates investments for the total switch, as well as the line port, processor-related, line CCS, MDF, and trunk CCS functional categories. The SS7 bucket is treated as the residual term in the switch estimation, and is forced to a value input by the user.[56] BCPM is supplied with default inputs of $150,000 for the DMS-100 and $300,000 for the 5ESS (non-discounted) for the SS7 equipment.

Use of the total investment equation for a "true-up" eliminates the possibility of a large cumulative error in the total investment that could be generated by adding together individual bucket estimations.

The steps in the host/standalone investment estimation process are as follows:

1. Estimate total switch investment using the regression coefficients.
2. Estimate the category investments using the regression coefficients: Port, Processor, Line CCS, MDF, and Trunk CCS.
3. Input SS7 residual category investment (from Global Defaults worksheet).
4. Calculate "adjustment ratio": (estimated total inv. – SS7 inv.) / (sum of estimated category inv. – SS7 inv.).
5. Multiply estimated category investment by the "adjustment ratio" to yield adjusted category investment.[57]

Estimate Remote Investments

BCPM assumes that no direct trunking takes place from remotes, hence the lack of a trunk term. SS7 equipment is likewise normally placed in hosts or standalones only.

[56] SS7 investment was treated as a residual since there was little variation across the switch types in the data sample used for the regression analysis.

[57] The purpose of steps 4 and 5 is to simply to "true up" the sum of the category investments by reconciling the sum with estimated total investment.

The steps in the remote investment process are as follows:

1. Estimate total switch investment using the regression coefficients.
2. Estimate the category investments: Port, Processor, Line CCS, and MDF.
3. Calculate "adjustment ratio": (estimated total inv.) / (sum of estimated bucket inv.).
4. Multiply estimated bucket inv. by the "adjustment ratio" to yield adjusted bucket investment.[58]

A test of this category investment estimation process is to determine the degree of prediction error; that is, the extent to which, on average, each estimated category investment differs from the actual investment. Table 5 presents these prediction errors. As indicated in Table 5, the prediction error is consistently very low and never exceeds 5%.

Table 5. Functional Category Investment Process Prediction Error.

	Total Investment	Processor	Line Term	Line Port	Line CCS	Trunk CCS	SS7
Stand Alone	-0.95 %	-1.59 %	-0.06 %	0.55 %	-1.16 %	-1.37 %	-2.26 %
Host	-1.18 %	-2.65 %	-3.34 %	-1.43 %	0.84 %	-2.25 %	-1.22 %
Remote	-1.97 %	-0.84 %	-1.67 %	-4.42 %	-0.95 %	NA	NA

Switch Curve Estimation Completed

The BCPM switch investments by functional category are now passed to the discounting module, which calculates the discounted investments (Figure 1, step 1.3). The discounted investments are then passed to the investment selection process (Figure 1, step 1.4).

[58] Since line termination investment does vary across the switches in the sample used in the regression analysis, an equation explaining such investment can be estimated. Hence, there is no "residual" investment category for remote switches.

Figure 1: BCPM Switch Functional Investment

Development Process

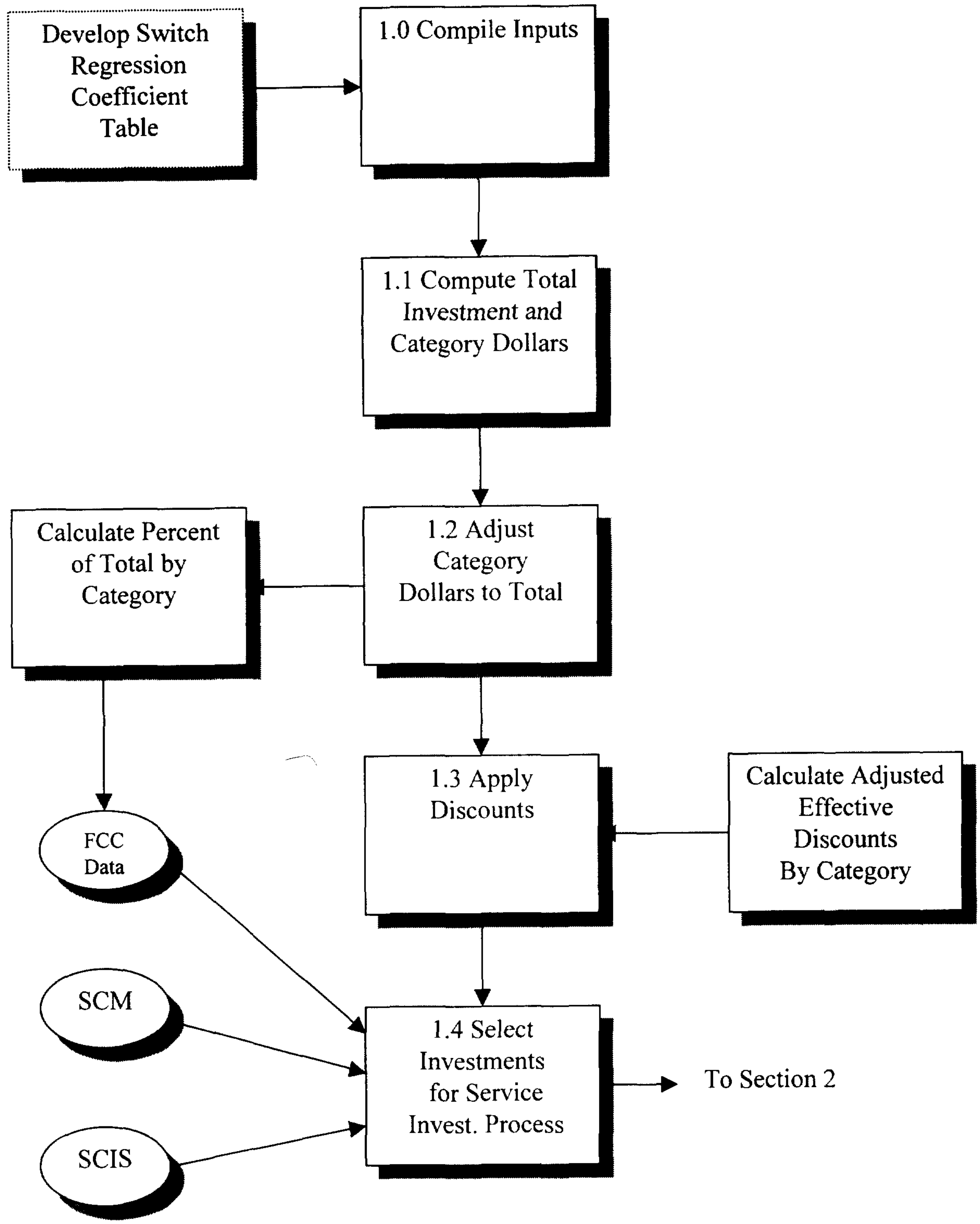
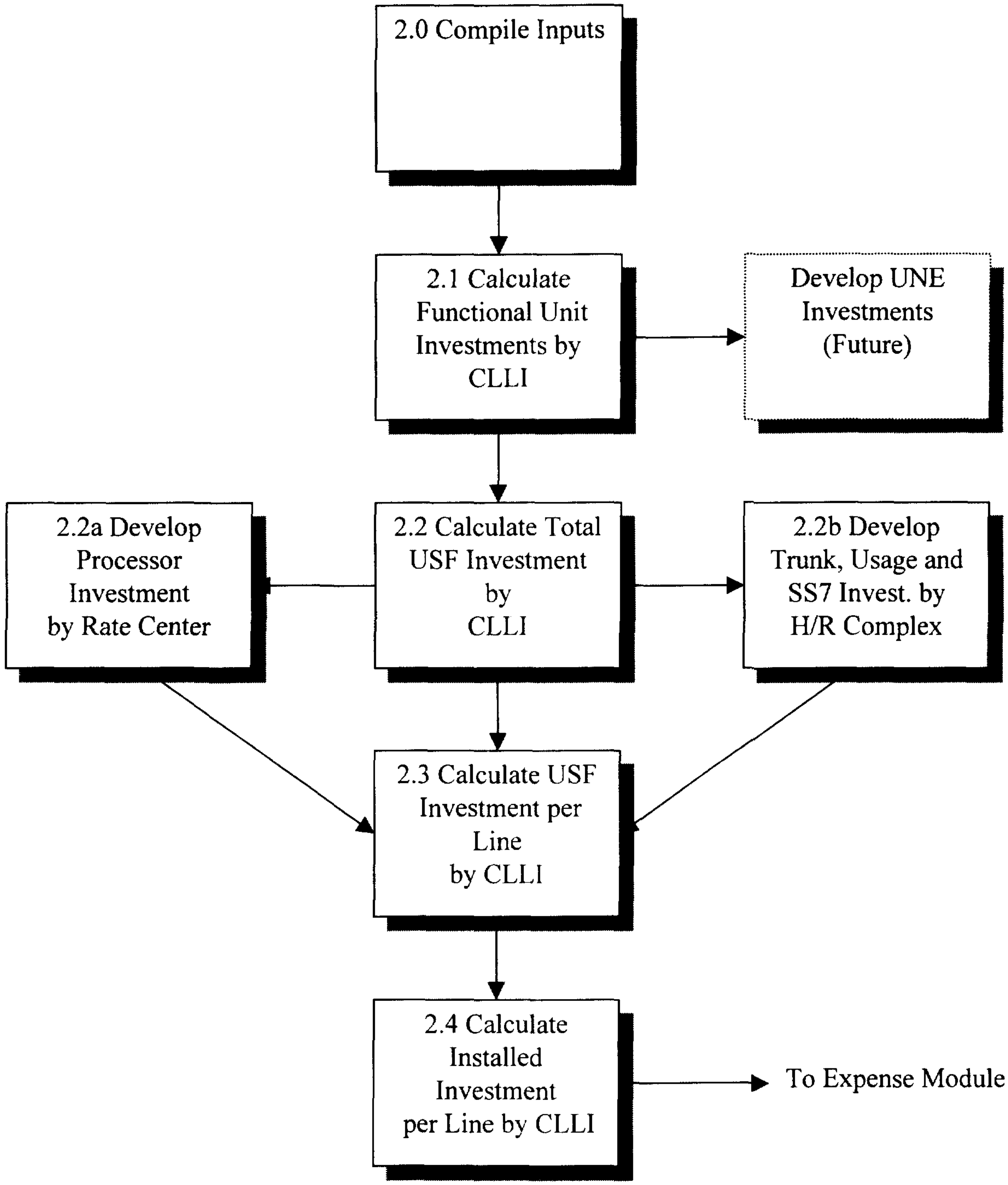


Figure 2: Service Specific Investment Development Process



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Benchmark Cost Proxy Model
Release 3.1

Loop Inputs Documentation

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Developed by
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Preface

The intent of this document is to discuss the input definitions, default values, sources and rationale for the individual loop module inputs for BCPM 3.1. Public information is used wherever available to populate the default values. Certain of the input values are tied to the USDA, Soil Conservation Service STAATSGO terrain database also used as model inputs. Default inputs relating to component pricing are an average of the many Local Exchange Carriers (LECs) that participated in the surveys conducted for version 1.1.

A more general discussion of the inputs for the switching module of BCPM 3.1 can be found in the BCPM 3.1 Model Methodology.

LOOP MODEL INPUTS

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